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Electrical drive system with one or more intercommunication networks

The invention relates to an electrical drive system for the synchronised adjustment of a plurality of rotatable axles or further, also linearly movable functional parts of devices and machines, in particular printing machines, in terms of their position, speed or acceleration. A plurality of drive units controlled using computer assistance are connected, according to the single drive technique which is known per se, to one or more functional parts for their adjustment.

In this context, it is known (Patent DE 196 33 745 C2) to form a plurality of separate drive networks, which respectively have a plurality of the said drive units as network nodes. The communication of these drive units with one another is carried out via a parallel bus system. Since, for example in the case when newspaper printing machines are being used, from 100 to 200 drives to be synchronised are by no means uncommon, this known patent proposes that a plurality of such drive networks be formed separately from one another and, according to a section of the machine or system, these individual drive networks be interlinked with one another via a cross- or intercommunication network and that they be synchronised, above all with one another, on a common master axis. For the intercommunication network, a ring topology is proposed with the communication taking place in accordance with the master/slave principle (cf. SERCOS interface, known per se). In this case, the bus masters of the respective drive networks form slave nodes of the intercommunication network, and a further bus master also functions as the bus master of the intercommunication network. In order that further machine sections can be

synchronised with the aforementioned machine section, the patent also proposes that the bus master of a first intercommunication network specify a synchronous clock via its master synchronisation telegrams, not only for the slaves of its network but also, via a communication interface inserted as an additional network node, for the neighbouring master/slave intercommunication network. The communication interface is in this case simultaneously a node of the neighbouring network. It is therefore possible for setpoint values, generated at a master level, to be distributed to a multiplicity of drives running in angular synchronism. Stringent requirements in terms of synchronisation can hence be satisfied. Even time shifts of the setpoint values by one µs lead at a high production rate (for example 35,000 print copies per hour) to an angular error of 3.5 millidegrees. On a printed paper, this can cause an offset between two colours of 0.01 mm (if the printing roll has a circumference of approximately 1100 mm) with corresponding disadvantages for the printing quality. However, the use of a parallel bus structure according to the patent in the respective drive networks leads to a high outlay on transmission and cabling. This disadvantage is exacerbated further when significantly large distances need to be covered.

To help, the drive system specified in Patent Claim 1 is proposed, which is distinguished from the said previously published patent by the fact that the drive units or nodes of the drive network are arranged in accordance with the master/slave principle and are respectively connected to one another in a ring structure through communication channels and/or a communication system. With the master/slave ring structure, the individual nodes or drive

units can advantageously be set for synchronisation to a common clock, with minimal outlay on cabling and installation. Furthermore, it is possible to cover larger distances than with the previously known use of the bus topology.

In relation to the drive system disclosed in the aforementioned patent, there is furthermore the requirement for increased reliability, availability and maintainability. In multi-axis applications, for example in printing machines, it is necessary to ensure that the failure of individual drive units, drive networks or of the intercommunication network interlinking them does not lead to failure of the entire machine system or of the entire drive system. Besides this, also to increase availability and maintainability, there is the further requirement that both logical and physical drive groups or networks can be formed with high flexibility. Therefore - to increase availability - it should be possible to switch off individual machine parts or machine systems without affecting the rest of the machine.

It is also an aim of the invention that, beyond the actual hardware network configuration, in principle any drives can be combined into logical groups or networks, to which different setpoint values are then applied. In the case of using printing machines in which each folding mechanism usually specifies a master axis, it should be possible to synchronise each printing mechanism with any folding mechanism for the definition of a paper web.

A further requirement is to supply drive groups with additional setpoint values which are independent of a centrally specified master axis and which are processed,

controller, to come to a standstill. The failed network and/or the failed machine section, after repair and with restarting, can again join in the data and command interchange in the multi-link controller. On the other hand, if the multi-link controller fails, each machine section or the associated intercommunication network can continue to run independently until, for example, defective cards or modules have been replaced. Owing to the structure according to the invention, it is possible at any time during continuous operation for intercommunication networks with associated machine sections to be isolated from the communication chain for maintenance work, which increases the maintainability.

According to the invention, the multi-link controller conducts comprehensive communication between the individual intercommunication networks. To that end, for each intercommunication network, it provides a network node which simultaneously forms a structural component of the multi-link controller. In this context, it is expedient for the functions of a communication manager to be implemented in the communication component of the multi-link controller. Preferably, the communication component is relieved from undertaking direct drive functions.

The basic function of the multi-link controller according to the invention consists in setting up information interchange of its communication components with the associated intercommunication networks. Such interchange will be incorporated into a data and command transfer encompassing the respective network topology only if it takes place synchronously with a clock of the multi-link controller (expediently embodied in the scope of a processor system integrated in it) and all nodes of the

intercommunication network are uniquely identifiable via the communication master (preferably the communication component of the multi-link controller).

The scope of the general inventive concept furthermore includes a multi-link controller, preferably designed as an independent structural unit, which is suitable for incorporation into the drive system according to the invention, owing to the fact that it has plurality of communication components or communication interfaces respectively configured as communication masters for external networks. The multi-link controller is furthermore provided with its own processor for controlling and regulating the communication interfaces.

The scope of the general inventive concept furthermore includes a drive synchronisation control unit which is designed, or is suitable, as nodes of an intercommunication network of the electrical drive system according to the invention. The drive synchronisation control unit according to the invention is essentially distinguished by at least one first communication interface and at least one processor, which controls it and is provided with the following modules:

- a master axis module, which is designed to receive, to generate and/or to route data and/or commands for a virtual master axis via the at least one communication interface;
- a data distribution module, which is designed for controlling a data and/or command flow via the least one communication interface with one of the aforementioned networks, in particular the intercommunication network.

Figure 1 shows a plurality of intercommunication networks interlinked via a multi-link controller,

Figure 2 shows the internal structure of the multi-link controller,

Figure 3 shows the internal structure of a drive synchronisation unit,

Figure 4 shows an intercommunication network with a plurality of connected drive networks,

Figure 5 shows the internal structure of a drive unit,

Figure 6 shows an intercommunication network in ring topology,

Figure 7 shows a plurality of annular intercommunication networks interlinked via a common multi-link controller,

Figure 8 shows a redundantly configured example of an annular intercommunication network,

Figure 9 shows an example of the use of an intercommunication network with a plurality of drive networks in a printing machine system,

Figure 10 shows the interlinking of a plurality of intercommunication networks, or allocated printing machine sections, via a multi-link controller.

Figure 1 shows an example with a multi-link controller MLC and three intercommunication networks 1.1, 1.2, ... 1.15, 3.1, 3.2, ... 3.31, 4.1, 4.2, ... 4.22 connected to it. The respective connection is carried out via the first, third and fourth communication interfaces SIM1, SIM3, SIM4 of the

this software module, the multi-link controller MLC can conduct the communication between the individual intercommunication networks. Individual data and/or command streams from one intercommunication network can hence flow via the multi-link controller, or its data distribution module, to another intercommunication network. In addition, filtering or other processing of data which is received and is to be routed can take place by means of the digital signal processor DSP. The filtering result with respect to data of a first intercommunication network is then conveyed by means of the multi-link controller to a second cross-communication network, the respectively allocated communication interfaces SI_ISR_x being switched on. For instance, it is possible to allocate a master axis function from a first intercommunication network to any drive units DRC (see Figures 4 and 5) of other intercommunication networks.

According to Figure 3, the drive synchronisation control unit also has, as its hardware core, a digital signal processor DSP. Implemented, or programmed, so as to be run via the latter are the following software modules:

- drive communication module DRV_COM_MGR, for organising a data flow from and to the respectively connected drive network (cf. e.g. Figure 4)

- master axis module VSA_MGR, for receiving, temporarily storing, generating and/or routing commands and data for synchronising the drive units of the connected drive network according to a virtual master axis

- data distribution module DTA_DIST_MGR, for organising an command and/or data flow from and to connected networks via, in the example shown, three communication interfaces.

According to the exemplary embodiments which are shown, the communication interfaces SI_PLC, SI_ISR, SI_DRV for serial data transmission are respectively configured via transmission and reception components TX and RX and are respectively intended, via communication channels 1, for connection to a superordinate process control network, to the intercommunication network belonging to the respective synchronisation control unit and to the respectively allocated intercommunication network. Whereas these communication interfaces are still substantially embodied with their own hardware elements, respective communication management modules COM_MANAGER are designed to be run on the signal processor DSP to operate them (as for the multi-link controller according to Figure 2).

Figure 4 shows the multi-network structure. The individual synchronisation control units SDC are connected to one another via their first communication interface SI_ISR, which is respectively intended for this, as nodes of an intercommunication network by means of preferably bidirectional communication channels 1 or a further communication system. Via the second communication interface SI_DRV, the synchronisation control units SDC respectively form a node of an allocated drive network with drive units DRC controlled using computer assistance. To form the drive networks, or to connect their nodes, communication channels 1 or a further communication system are likewise provided. To each electrical drive unit DRC, which, in particular, comprises an electric motor 2, are

allocated one or more mechanically movable functional parts 3 for their adjustment with respect to position, speed or acceleration. The nodes of the individual drive networks SDC0, DRC1, DRC2, DRCn; SDC1, DRC1, DRC2, ..., DRCn;... and of the intercommunication network SDC0, SDC1, ..., SDCN expediently access the communication channels 1, which are interlinked with one another, or the communication system or the further communication media in accordance with the master/slave method which is known per se. The data transfer expediently takes place synchronously in the two networks. In this case, in the drive networks, the synchronisation control units SDC0, 1, ..., N from the intercommunication networks respectively form the communication master with independent transmission right. Inside the communication network, a first synchronisation control unit SDC0 forms the communication master with respect to the others SDC1, SDC2, ..., SDCN.

According to Figure 4, the individual nodes or synchronisation control units SDC of the intercommunication network can interchange commands and data with a master control level, or a process control network PLC, via respective third communication interfaces SI_PLC. In particular, owing to large amounts of data to be transmitted, the data transfer takes place asynchronously here.

According to Figure 5, the drive unit SDC has, as basic hardware elements, a communication interface SI_DRR with transmission and reception components TX, RX, a converter interface CONV_INTERFACE and a digital signal processor DSP that regulates and controls the latter. Runnable thereon, the drive unit DRC also comprises the following software modules:

According to Figure 7, in order to achieve a modular communication structure, a plurality of intercommunication networks are arranged running parallel respectively in a ring structure with master/slave hierarchy. The multi-link controller MLC in each case provides a master node SIM1, SIM2, which comprise the aforementioned communication interfaces, for the two represented intercommunication networks SDC M1, SDC S1, SDC S2, SDC S3 (first intercommunication network) and SDC M2, SDC M3, SDC S4 (second intercommunication network). The communication masters SIM1, SIM2 from the multi-link controller MLC (in practice, embodied by means of a SERCOS interface card) are not provided with direct drive functions. Conversely, all further nodes or drive synchronisation control units can in principle operate and guide a preferably annular drive network, i.e. they can function as communication masters or master nodes for it. Via corresponding data and command interchange with the multi-link controller MLC, particular synchronisation control units SDC can be defined either as masters with a master axis function (Mx: SDC master) or as slaves without a master axis function (Sx: MDS slave).

A maximum number of synchronisation control units SDC is then obtained, as a function of the number of intercommunication networks, from the following conditions:

- The maximum number of synchronisation control units SDC, i.e. the sum of masters and slaves; per intercommunication network is equal to 32

- The maximum number of SDC masters in the entire system is equal to 31.

Example: if six intercommunication networks of a system were each equipped with five SDC masters, up to 27 SDC slaves could also be inserted per intercommunication network.

The failure safety of the entire system is improved by the fact that, if one of the intercommunication networks fails, the remaining communication via the multi-link controller remains unaffected by this. After restarting, the intercommunication network that failed and has been repaired can again join in the data interchange via the multi-link controller. This advantage is also obtained from the star structure with the multi-link controller MLC as the star centre.

The configuration represented in Figure 7 also provides the opportunity of sending communication control and/or command signals, which have been generated by a master node SDC Mx of one intercommunication network, via the multi-link controller to the slave nodes SDC Sx of another communication network.

With the multi-network structure represented in Figure 7, having the multi-link controller MLC as the star centre, an existing machine section, operated with a single intercommunication network, of a mechanised system can be expanded or upgraded by further machine sections with new intercommunication networks, even if the communication networks have different software versions. To that end, the multi-link controller MLC is designed, by using program and/or circuit technology, in such a way that it can convert the communication protocol of an older-version intercommunication network into another communication protocol of a second, newer-version intercommunication

network (so-called protocol converter). For the storage of received data according to its protocol, it is expedient to provide the multi-link controller with a reception storage unit (not shown in the drawings) for such data.

The multi-link controller does not need data input and output in relation to an operator from a workstation or from an intercommunication network. It is expedient, however, to provide the multi-link controller with a facility for separate parameterisation and an interface to an external error diagnosis system, for example a superordinate process master control PLC (not shown).

In Figure 8, to increase availability, the star structure according to the invention with the multi-link controller MLC is redundantly designed. On the basis of the jumper cabling, two participants or nodes in a communication ring can in principle fail without this leading to failure of the entire ring. The redundant structure can be produced both for drive networks in ring form and for intercommunication networks in ring form. By using the multi-link controller MLC, it is also not a problem for individual intercommunication networks corresponding to individual machine sections to be removed from the group for maintenance purposes and later reactivated via the multi-link controller MLC. The drive structure according to the invention hence not only serves for clarity, but also contributes crucially to high availability of the printing machine system, which is required above all in newspaper printing machines.

According to Figure 8, the possibility of the following operating nodes is obtained for each machine section:

- Intercommunication operation: the multi-link controller MLC is activated and the respective machine sections are switched to it. All drive synchronisation control units SDC are slaves, in the scope of the intercommunication network comprising them, with respect to the master node of the multi-link controller.

- Separate operation: the multi-link controller is activated, but at least one machine section and the associated intercommunication network are switched off.

- Single operation: the multi-link controller is deactivated, even if the one or more machine sections with associated intercommunication networks are switched on. One of the nodes, or one of the synchronisation control units SDC, of the communication network switches over to the role of the communication master dominating it.

In the this way, on the one hand, redundancy is guaranteed if the multi-link controller MLC fails and, on the other hand, the release of a machine section for maintenance work can also be controlled as viewed from the side of the intercommunication network. According to an advantageous configuration, the switchover of a machine section from the operating mode of "intercommunication operation" to "single operation" is possible in real time. In this way, the communication networks per se can be configured flexibly.

Figures 9 and 10 represent examples of the use of the drive system according to the invention respectively without and with a multi-link controller in a printing machine system

having a large number of printing towers 4 and a plurality of folding mechanisms 5, as known to the person skilled in the art.

According to Figure 9, three annular drive networks are respectively formed with eight drive units DRC for the printing towers 4 and the folding mechanism 5. In this case, the master function or the role of the communication master for the drive rings, each of which communicate synchronously, is in each case allocated to one of the drive units. A drive network corresponds to the drive equipment of a complete printing tower 4. The annular drive networks operate in accordance with the master/slave method with synchronous data transmission (corresponding to the SERCOS interface which is known per se). The drive unit respectively having the master function is coupled via the Ethernet, which is known per se, to a control UNIT and undertakes the task of supplying all drive units 2...8 allocated to it with the synchronised setpoint values and control signals intended for them. Likewise, the status information from all coupled drive units is combined here and made available to a master level via Ethernet. Besides the operation of its own drive, the drive unit dominating the drive network as a communication master may also undertake a master axis function. The printing tower 4 equipped in this way can hence be regarded as a building block of a complex printing machine section or printing machine. The interlinking of these building blocks (in the example application: printing towers 4) to facilitate intercommunication between the drive masters takes place through a second, synchronously communicating master/slave network - the intercommunication network (SERBAS) - which likewise connects the drive networks or rings physically

according to a ring topology corresponding to the SERCOS interface. In practical exemplary embodiments, the intercommunication network SERBAS may consist of up to 32 communication partners or network nodes. This intercommunication makes it possible for drives or drive rings to be allocated to a virtual or even a real master axis. The resulting drive groups correspond, in the application example which is represented, to the path of a paper web through the printing machine system. In general, the role of the master axis will be given to a folding mechanism 5. This means that all drives allocated to this master axis must be synchronised to the absolute position of this master axis, or of the folding mechanism. In a machine or a part/section of it, in practical application examples, it is possible to define up to 32 such master axes, to which any drive units may respectively be allocated. The essential information which needs to be distributed via the intercommunication is the web-specific setpoint speed values as well as the associated control and status information. This gives rise to a new building block, which represents an independent sub-machine or a machine section of a complex system.

According to Figure 10, the individual sections (in the example which is represented, seven sections 1..7) are interlinked with one another and managed via the multi-link controller MLC. A participant or node SIM 1...7 which does not undertake any drive function is included in the annular intercommunication network of each section. This intercommunication network node is simultaneously part of the multi-link controller MLC which, according to the state of the art, can manage up to seven intercommunication rings or networks. This gives, as the number of drive units to be

operated synchronously: 48 (per drive network) × 31 (per intercommunication network) × 7 (per multi-link controller) = 10416. The multi-link controller MLC provides each section, or each associated intercommunication network, with all information needed for allocating each drive unit DRC present in a machine section to one of the 32 possible master axes. This facilitates the construction of drive configurations that are very complex, yet can be structured well. Since the drive structure also reflects the mechanical structure of the machine, complex systems with many drives also gain in clarity and therefore become easier to control and operate.

In addition to the physical network structures, which are frequently based on the actual mechanical layout, it is also possible to form and define independent logical (network) structures. Each drive can hence be allocated to one of, for example, 32 drive groups or networks. The groups formed in this way can be supplied with additional group-specific setpoint values. These group setpoint values may be independent of any master axis, although they likewise need to be implemented in synchronism. In this case, it is possible to define a group master which is independent of the master axis, and to which other group members are synchronised. In the application of printing machines, such functions are used in set-up operation for the intake of paper webs, or also for the synchronisation of a plurality of paper webs.

According to an advantageous refinement, the setpoint values may be specified by the control level (UNIT CONTROLLER) via the Ethernet connection to the nodes of the drive networks functioning as communication masters. Since, with the methods described above, synchronisation of the

drives in the system is ensured, the specification of the web-specific setpoint speed values may take place asynchronously via Ethernet interfaces. In this case, the protocols TCP, UDP and IP may also be employed. A central diagnosis PC may be coupled, at least in terms of information technology, with each drive unit via the Ethernet. Besides diagnosis and operation, this provides the opportunity for central management of all relevant parameterisations in the system. Through ISDN or modem connection of the diagnosis PCs, any system worldwide can be reached for teleservice or error diagnosis.

List of references

1	communication channels
MLC	multi-link controller
SIM	master communication interface
SDC	synchronisation control unit
Tx	transmission component
Rx	reception component
DSP	digital signal processor
DRC	electrical drive unit
2	electric motor
3	functional part
PLC	process control network
4	printing tower
5	folding mechanism